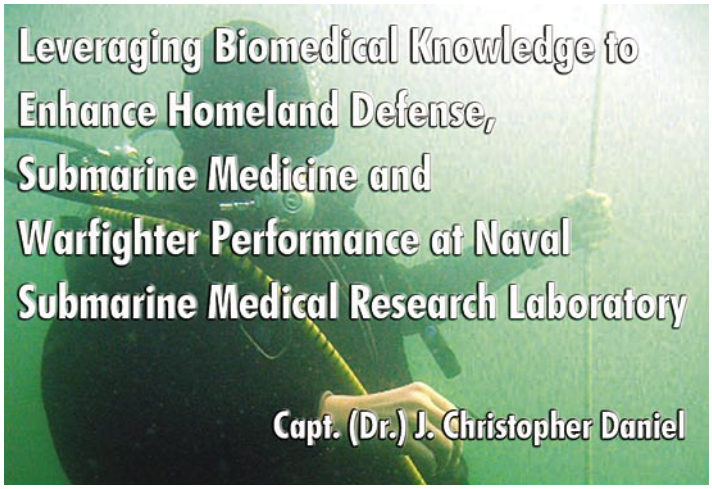


NSMRL on the Frontlines of the GWOT

A Coast Guard Maritime Security and Safety Team, acting on a tip from a law enforcement agency, stakes out the water around a nuclear power plant. Suddenly, the Integrated Anti-Swimmer System detects a swimmer stealthily approaching. When a verbal warning delivered by an underwater loudspeaker does not halt the diver's progress, bursts of high-pressure air delivered through a submerged air gun create powerful low frequency impulses that cause disorientation and physical pain. The diver, startled and hurt, immediately surfaces and is captured, thus thwarting a planned terrorist attack.

Scientists from the Naval Submarine Medical Research Laboratory (NSMRL) were involved in the development and evaluation of these terrorist-thwarting devices. The lab provided many of the design parameters and performed much of the testing for the various components of the Integrated Anti-Swimmer System and the related Diver Interdiction System.

NSMRL's Dr. Ed Cudahy has studied the human bioeffects of underwater sound for many years to protect our fleet and Special Operations Forces (SOF) divers. In the last three years, he has applied his vast knowledge to evaluating and validating various elements of potential non-lethal anti-swimmer systems for safety and tested the effectiveness of deterrent sounds for the Joint Non-Lethal Weapons Directorate, Coast Guard and Navy.

The impact of this work is enhancing our nation's homeland defense and the protection of our nation's military assets. These are just two examples of the myriad operational applications of the research conducted at this Navy Medicine laboratory, located a few hundred yards from the waterfront at Submarine Base New London, Groton, Conn. *Why is NSMRL, whose mission is to protect the health and enhance the performance of our warfighters through focused submarine, diving and surface research solutions, on the frontlines of the global war on terrorism (GWOT)?* One must look at our history for the answer.

A Proud History

In 1942, the Medical Research Section of the U.S. Submarine Base New London dispensary was tasked to provide "answers to problems in communications, vision, personnel selection, and environmental medicine which resulted from wartime demands on the submarine force." Because of the critical importance of submarines during World War II, the lab's work quickly expanded to include studies on night vision, color vision and lookout training.

When the lab was officially established as a Medical Research Laboratory in 1946, its three-fold mission included: selection of personnel for training in the Naval Submarine School (SUBSCOL); instruction of hospital corpsmen (HM) and medical officers in Submarine Medicine; research in medical aspects of submarine duty and diving, including night and color vision; human engineering; and personnel selection methods. Although the mission of educating medical officers and independent duty corpsmen in Submarine Medicine now belongs to the Naval Undersea Medical Institute (also at Submarine Base New London), NSMRL continues to screen SUBSCOL candidates and perform submarine and diving research.

NSMRL has a proud history of valuable contributions to the Navy and to our nation's defense. In the 1960s, the Submarine Force established the appropriate mission duration in the new ballistic missile nuclear submarines based on NSMRL psychological research aboard USS Triton (SSN 586) during its circumnavigation of the globe.

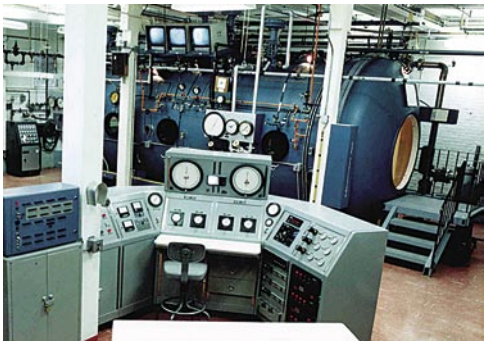
In the field of human vision, NSMRL's work has resulted in the Navy being able to safely and optimally utilize the talents of many personnel with less than perfect vision, through work that showed that these personnel performed as well as those with perfect vision by inserting refractive corrections into periscope optics. Other vision-related work resulted in the replacement of "rig for red" viewing in sonar and control rooms with low level white lighting, and the development of both the International Orange color (air-sea rescue red) for visibility and the Farnsworth Color Lantern Vision screening test.

Experiments by Drs. George Bond and Robert Workman at NSMRL in the late 1950s and early 1960s explored the feasibility of saturation diving, confirmed the suitability of helium-oxygen breathing mixtures, and ultimately resulted in landmark studies that proved it was possible to safely live and work for two weeks at 200 feet, first in NSMRL's "Genesis I" hyperbaric chamber (still in active use, see the photo on the next page) and then in "Sea Lab I" on the ocean floor near Bermuda.

Other studies in NSMRL's hyperbaric chambers produced many of the Navy saturation diving and decompression tables that are still in use around the world today. In 2005, the lab was honored with its first Meritorious Unit Commendation, an award long overdue, according to none other than the Navy's Surgeon General and Chief, Bureau of Medicine and Surgery (BUMED), Vice Adm. Donald Arthur, who himself authored six reports while serving at NSMRL.

Submarine Force Health Protection

Today, the lab performs cutting edge research in health and safety, operational performance, and submarine survival and escape. Dr. Cudahy's work has its roots in protecting the safety of Navy divers, and much of NSMRL's work involves other health or safety efforts. The challenges posed by the submarine's unique



Left – The Genesis Hyperbaric Chamber at NSMRL. Middle – Air sampling wafer packages used to monitor atmospheric conditions aboard deployed submarines. Right – USS Maryland Gold crew member undergoing physiological testing while underway.

environment and operating conditions place a premium on ensuring the safety and health of the crews. This includes the air they breathe, the physical and mental health risks of being submerged for long periods, the noise surrounding them, and tools to help them survive casualties at sea.

While underway, submariners are continually in a closed environment and the atmosphere must be closely monitored to ensure that it does not pose a potential hazard to the crew. While automated systems continuously measure levels of the most critical gases, including oxygen and carbon dioxide, the recycled nature of the submarine atmosphere means that possible contaminants must be monitored on a long-term basis. Even ordinary materials can give off harmful gases.

The Closed Living Space Environmental Concerns Working Group, in which NSMRL plays a key role, advises BUMED on biological, operational and engineering interactions of submarine atmospheric contaminants and recommends acceptable limits for these contaminants. These limits are generally well below comparable standards for shore environments.

The Submarine Atmosphere Health Assessment Program, an ongoing partnership between NSMRL and Naval Sea Systems Command (NAVSEA), has developed wafer-like sensors (see photo above) that measure levels of airborne contaminants during deployments. After the boat returns to port, the wafers are analyzed ashore, and the results are reported to the boat's commanding officer. The at-sea measurements are supplemented by analyzing additional compounds during comprehensive submarine atmosphere sea trials. Sampling techniques include using vacuum bottles to draw air samples over a brief time. For example, the atmosphere onboard USS Virginia (SSN 774) was recently tested during her sea trials to ensure that new equipment and products pose no hazard to the crew.

Submariners receive no sunlight while underway. During prolonged submergence, this can lead to Vitamin D deficiencies, another health risk that NSMRL has studied. One solution that would likely be popular with Sailors, liberty in a tropical port, is generally not feasible for operational reasons. A less exotic alternative is available: periodic large doses of Vitamin D.

Although all submariners are volunteers, there are high physical and psychological standards that all Sailors selected for submarine duty must meet. The Navy's Manual of the Medical Department mandates this special screening. NSMRL has been evaluating Sailors' suitability for submarine service since World War II. Since 1986, NSMRL has been using SUBSCREEN, a self-report psychological test, to screen for potential risk factors, including claustrophobia, suicidal ideation and depression. Sailors who flag for one of these risk factors are referred to the base clinic for psychological evaluation. Based on the clinic's evaluation and recommendations, SUBSCOL command personnel decide whether to retain or release the individual.

About three percent of students are removed from the submarine force before going through SUBSCOL courses, saving both money and time. However, many who remain are ultimately unsuccessful in their Navy career. They leave for negative causes, are not promoted and do not finish their first enlistment. Using the lab's database of more than 30,000 former and current submariners, NSMRL has determined that a subset of the SUBSCREEN test effectively predicts which people are more likely to fall into the unsuccessful category. That information is now being used to determine whether early intervention in SUBSCOL can help reduce attrition.

NSMRL's expertise and experience in the realm of psychological screening was recently leveraged at the Naval Service Training Center, as part of the Navy's efforts to maximize its return on human capital. An initial test of NAVSCREEN, based closely on SUBSCREEN but generalized for use with incoming Sailors, was administered to a group of recruits at the Recruit Training Command. The Naval Education and Training Command will closely examine the results of this test for possible full implementation as a screening aid.

NSMRL determines the extent to which physical ailments, such as kidney stones, could impact a submariner's ability to deploy to sea. By allowing those at low risk to ship out, the Navy retains the services of highly trained Sailors and keeps careers intact.

An area of expertise and ongoing work at NSMRL that is relevant to other warfare communities is exposure to damaging levels of noise. Noise-Induced Hearing Loss (NIHL) represents the Veterans Administration's single largest bill for a service-related disability. Yet, despite the huge prevalence of this problem, Sailors notoriously do not use available hearing protection. To address this challenge, Dr. Lynne Marshall at NSMRL is currently developing a hearing-loss simulator for the Office of Naval Research.

This interactive device presents an auditory "picture" of what the future might sound like to a Sailor who doesn't use hearing

protection (and whose hearing has already begun the insidious NIHL decline, though the Sailor may not yet realize it). Experiencing the difficulty that someone with NIHL has in understanding phone conversations, appreciating music, hearing a baby cry or listening to whatever else matters most to each individual, could be a powerful motivator to change behavior.

A further advance in NIHL prevention may result from research that Dr. Marshall is conducting to see if otoacoustic emissions, minute sounds that the ear produces in response to external sound stimuli, can predict future hearing loss. Early evidence for this hypothesis was provided by research with USS Eisenhower (CVN 69) crew members. If additional research confirms these findings, the Navy could provide hearing protection targeted to specific individuals or transfer them to alternate, quieter worksites. This technology could be particularly valuable for the submariner, who is in a continuous low-level noise environment while underway.

The Navy's submarine independent duty corpsmen must listen to crew members' hearts and lungs in this noisy environment, an especially challenging task using the traditional stethoscope. Mr. Joe Russotti, who has worked at NSMRL for more than 35 years, is currently working to develop an electronic stethoscope for military use, ensuring that *abnormal* heart and lung sounds are preferentially amplified. Like NSMRL's hearing conservation focus, this effort to improve diagnostic capabilities in noisy environments has found considerable interest in the Marine Corps and in other Navy warfare communities.

NSMRL is frequently tapped by the fleet to get short-term answers not requiring a formal research study. In the realm of onboard medical care, the lab recently issued specific recommendations regarding the availability of oxygen dedicated for medical use onboard submarines. A lab team is currently evaluating optimal stretcher designs for use in the narrow passages aboard a submarine.

Improving Human Performance

With its work in Human Performance, NSMRL plays a leading role in researching ways for warfighters to perform their missions more effectively. One important component of performance is alertness. Trying to reduce fatigue and circadian rhythm (CR) disruption in the crew during submarine operations is one area of NSMRL research.

Lt. Cmdr. Loring Crepeau and HM2 Kevin Mathiau recently accompanied Sailors on USS Maryland Gold (SSBN 738) for a month underway, collecting physiological, behavioral, psychological and survey data as the crew followed an alternative watch schedule (see photo on page 37).

The Submarine Force for the past 40 years has utilized a "6 hours on, 12 hours off" watchstanding schedule. However, the pace of operations and the CR disruption inherent in this cycle means that crew members rarely get even six hours sleep per day. Moreover, the sleep they do get is of poor quality and fails to fully restore their performance. Because the submariner's "day" is 18 hours long, the CR pattern is constantly shifting — the equivalent of flying eastward through six time zones every 18 hours — causing further loss of alertness.

In fact, CR disruption alone makes it highly likely that every crew member will stand watch at a low point in the natural sleep/wake (and thus performance) cycle. There is strong evidence that a watch schedule approximating a 24-hour day could provide immense benefits in alertness and performance; but the challenge is to find one that also accommodates the boat's operational requirements.

For the Maryland Gold trials, the Engineering Officer, Lt. Cmdr. Matthew Phaneuf, devised such a schedule. Supported by the boat's chain of command, the trial went off without adversely impacting the boat's normal routine, operations or drills. For this submarine, at least, the alternate eight hours on, 16 hours off watch schedule improved overall alertness, increased sleep quantity and quality, and was well received by the crew. NSMRL is now planning a similar sea trial aboard a fast-attack submarine.

Even a well-rested crew needs to maintain optimal situational awareness. What are the best ways to display information in the sonar suite and the command center, especially when coming to periscope depth in a multi-contact environment or during other highly stressful maneuvers, each of which requires rapid integration of multiple inputs to maintain situational awareness? NSMRL has addressed this issue in several ways. Mr. Russotti, in conjunction with Naval Undersea Warfare Center, Newport, R.I., has developed a unique signal processing and display technique for collision avoidance that more than doubles the distance at which a contact can be reliably detected.

This is accomplished by taking advantage of the human's binaural capability to compare different sounds arriving in each ear, similar to the "cocktail party effect" that allows you to hear your name when it is mentioned in a noisy room. Using the human auditory system's automatic ability to filter sounds improves target detection by almost seven decibels.

NSMRL's Dr. Tom Santoro, in collaboration with Dr. Greg Wakefield of the University of Michigan, is working to enable simultaneous auditory detection and tracking of multiple sonar contacts by creating a virtual 3-D environment using standard headphones. They have demonstrated that a critical transient sound can be detected from among 10 distractor sounds with 85 percent accuracy using this spatialized 3-D audio presentation, while a change in course in one of four steady-running sonar contacts can be detected with 90 percent accuracy.

In other sonar work, NSMRL and NAVSEA engineers have collaborated to upgrade sonar audio digital signal processing specifications. NSMRL has worked closely with manufacturers to develop new extended fidelity noise-canceling headphones allowing sonar operators to hear sounds much more clearly. These headphones are currently deployed on Virginia-class submarines.

A successful crew must do more than avoid fatigue and maintain situational awareness; it must achieve and maintain *situational*

SEIE suit

superiority at all times. Optimal command-level decision-making that keeps the submarine safe and stealthy and results in successful mission execution is a key focus area for Commander, Naval Submarine Forces (COMNAVSUBFOR).

NSMRL has studied situational awareness among submarine officers and is now partnering with Klein Associates, which has worked extensively on improving team decision-making in firefighters and personnel in hospital intensive-care units and other high-stress environments. NSMRL is also working with Micro Analysis and Design, Inc., which supports computer modeling and simulation technology for decision-making and human-computer interface design. Together with Submarine Development Squadron Twelve, NSMRL, its industry partners and the Human Performance Center are addressing critical aspects of command decision-making processes in submarines.

Preparing for a Worst Case Scenario

New threats in the global war on terrorism have increased submarine operations in shallow waters near unfriendly coasts in operations sometimes involving Special Operations Forces. In fact, SOF insertion capability was a primary consideration in the development of Virginia-class submarines and the upcoming "SSGN" class, the group of former Trident class "SSBNs" (ballistic missile submarines) now undergoing conversion.

Despite the best efforts of a highly trained crew operating the most capable boat, unusual circumstances in littoral waters could cause a casualty that leaves a submarine disabled and submerged (DISSUB). Surviving SOF and boat crew members would then be forced to try to stay alive, possibly for days until rescue, or be faced with escaping from the boat and floating individually to the surface. Dr. Wayne Horn and his team at NSMRL have dedicated considerable effort in developing survival and escape equipment and procedures.

NSMRL is an integral member of COMNAVSUBFOR's Submarine Escape and Rescue Review Group, and is responsible for ongoing revisions for the Disabled Submarine Survival Guide, the Guard Book. Over the last decade, NSMRL has contributed to the deployment of numerous technological advances in use today, including: Submarine Escape Immersion Equipment (SEIE) suits (shown above); the Submarine Escape and Rescue Calculator, a PDA-based analytic software to facilitate Senior Survivor time-remaining determinations; portable gas analyzers; and passive carbon dioxide-scrubbing Battelle curtains, an underwater lifesaver for stricken submarine crews.

Dr. Paul Weathersby and others at the lab are now also exploring the possibility of escape from depths greater than 600 feet. Finding survivors who do escape can be difficult, and NSMRL is testing new infrared reflecting streamers to enhance detection of DISSUB survivors at sea.

COMNAVSUBFOR's goal is for the crew of a disabled and submerged submarine to have a survivable environment for up to seven days while awaiting rescue. With this in mind, in March 2003 and December 2004, the lab conducted survival exercises (SURVIVEX) with crew members on USS Dallas (SSN 700) and USS Salt Lake City (SSN 716), respectively. In these pierside exercises, conducted with Submarine Development Squadron Five, ship's power was shut off and external hatches were closed to evaluate DISSUB equipment and procedures.

The exercises confirmed the ability of the carbon dioxide-scrubbing curtains and oxygen release system to maintain a breathable atmosphere during DISSUB conditions. It appears that COMNAVSUBFOR's goal of seven-day survivability is definitely realistic in 2006. A surprising finding in these exercises has produced a new challenge for DISSUB research. Although it had been expected that a DISSUB would experience lower internal temperatures and create a risk for hypothermia, the opposite occurred. Survivex 04 was terminated early due to the increase in ambient temperatures and the resultant heat injury risk.

Facing the Future

Technology has advanced greatly since the days of WWII diesel boats. SEIE suits have replaced the Momsen Lung, noise-canceling headphones have replaced old headsets, computers have increased sonar sensitivity. Despite these advances, both the human element and the undersea environment remain unchanged. The importance of maintaining health and safety and of improving performance remains as critical today as it was in 1942. As each challenge has been mitigated or solved, another has risen to take its place.

For more than 60 years, NSMRL has tackled the biomedical challenges of the Submarine Force and our nation's warfighters. Just as the fleet has come to expect, Naval Submarine Medical Research Laboratory's dedicated people remain ready to adapt, improvise and overcome the challenges of the future.

Capt. (Dr.) J. Christopher Daniel is a Fellow, American Academy of Family Physicians (FAAFP) and commanding officer of the Naval Submarine Medical Research Laboratory.

For more information about NSMRL go to http://www.nsmrl.navy.mil/. CHIPS